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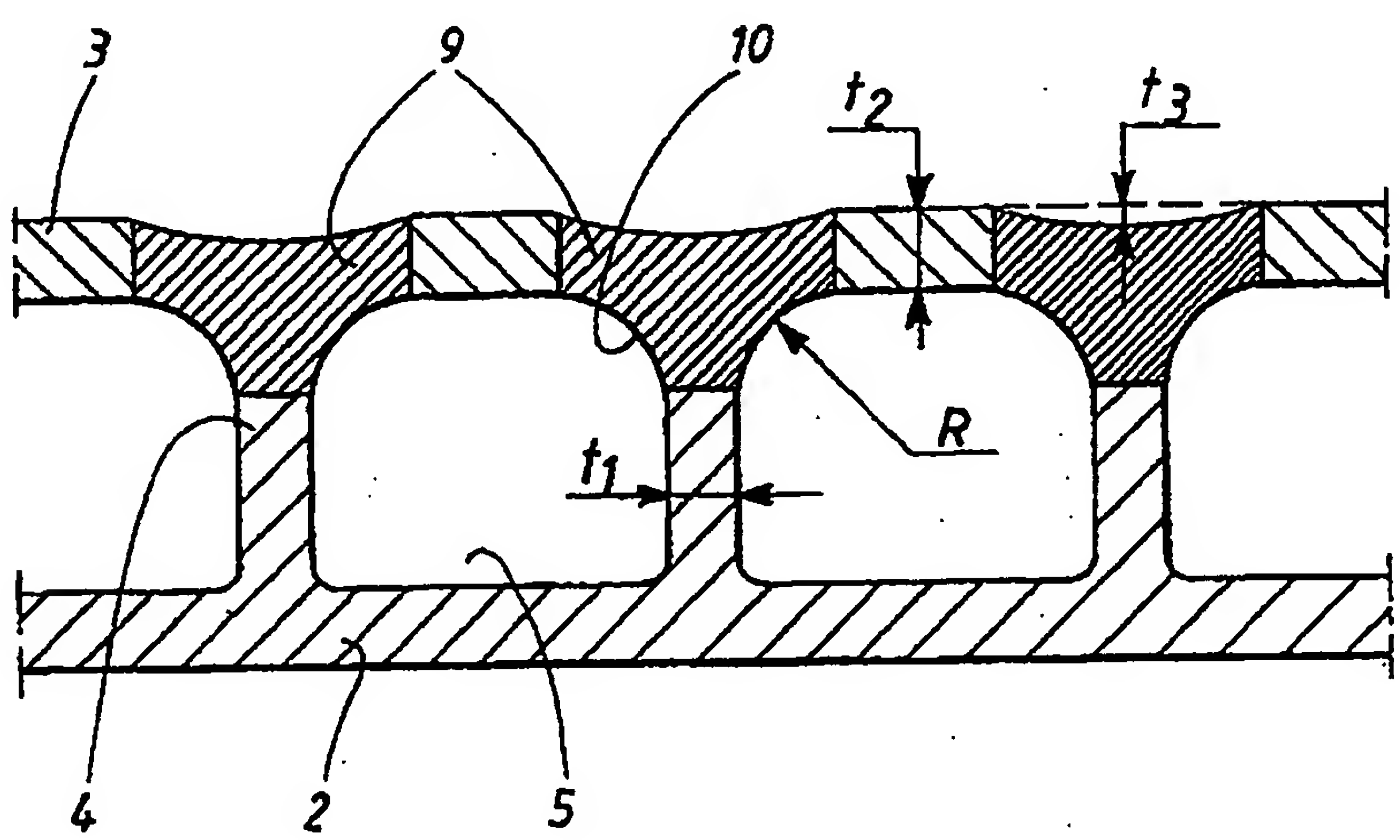

(57) Abstract

The invention relates to a method for manufacturing an outlet nozzle (1) for use in rocket motors, which outlet nozzle (1) is configured with a wall structure comprising a plurality of mutually adjacent cooling ducts (5; 5') extending substantially from the inlet end (6) of the outlet nozzle (1) to its outlet end (7), which method comprises positioning of an outer wall (3) around an inner wall (2), configuration and positioning of a plurality of distancing element (4; 4') between the said outer wall (3) and the said inner wall (2), and joining of the said distancing elements (4; 4') between the said inner wall (2) and the said outer wall (3), whereupon the said cooling ducts (5; 5') are formed. The invention is characterized in that the said joining is realized by means of laser-welding and is arranged for the configuration of weld joints (9; 9') which, in a cross section through the wall structure, are substantially T-shaped and have a shape (10) which is rounded towards the inside of the cooling ducts (5; 5'). As a result of the invention, an improved manufacture of an outlet nozzle is obtained, more particularly offering low weight, low cost and optimal cooling properties.

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Method for manufacturing outlet nozzles for rocket engines.

TECHNICAL FIELD

The present invention relates to a method for manufacturing outlet nozzles for rocket motors, according to the preamble to the subsequent claim 1. The invention is especially intended for use in respect of cooled outlet nozzles for rocket motors driven by liquid fuel.

PRIOR ART

Rockets is the collective name given to those crafts which comprise a drive source in the form of a rocket motor. Rockets are currently used, inter alia, for space-flights and in this context, for example, for research and for communications purposes. Rocket motors are also used in other contexts, for example in apparatus for aiding the take-off of aircraft and for ejecting the pilot from an aircraft in emergency situations.

In a rocket motor, the energy for propulsion of the rocket is generated in a combustion chamber through the burning of a fuel, for example in the form of liquid hydrogen. This fuel is fed together with an oxidizer (for example in the form of liquid oxygen) via valves to the combustion chamber. As the fuel is burnt, combustion gases are generated in the combustion chamber. These combustion gases flow out rearwards from the combustion chamber and out through an outlet nozzle, whereupon a reaction force is generated such that the rocket is propelled forwards. The outlet nozzle is configured to allow expansion and acceleration of the combustion gases to a high velocity such that the necessary thrust is attained for the rocket. The fact that a rocket motor can generate very large drive forces and can additionally operate independently of the surrounding medium makes it especially suitable as a means of transport for space-flights.

Whilst a rocket motor is running, the outlet nozzle is subjected to very high str ss s, for example in the form of a very high temperature on its inside (in

the order of magnitude of 800 K) and a very low temperature on its outside (in the order of magnitude of 50 K). As a result of this high thermal load, stringent requirements are placed upon the choice of material, design and manufacture of the outlet nozzle. Not least, there is a need for effective cooling of the outlet nozzle.

In order to achieve optimal cooling, the outlet nozzle according to the prior art is configured with a number of cooling ducts which are arranged in parallel within the actual nozzle wall and extending between the inlet end and the outlet end of the outlet nozzle. The manufacture of the outlet nozzle, that is to say the configuration of its wall such that the necessary cooling ducts are formed, can be carried out using a host of different methods.

In this context, it is also the case that high efficiency can be obtained in a rocket if the cooling medium is also used as fuel. For this reason, there is often a desire to re-use all the cooling medium for burning in the combustion chamber.

A previously known method of manufacturing a cooled outlet nozzle is by configuring the nozzle wall from a large number of round or oval pipes made of, for example, nickel-based steel or stainless steel, which pipes are arranged close together and are subsequently joined together along their sides. This joining can in this case be realized by means of soldering, which is however a manufacturing method which is relatively costly. Moreover, the soldering results in an increase in weight of the outlet nozzle. The soldering additionally represents a complicated and time-consuming operation in which it is difficult to attain the necessary strength and reliability in the completed wall structure.

Another significant drawback with solder-based joining is that it is complicat d and expensive to check the solder joints. If, for example, a fault occurs along a solder joint, it is very difficult to repair the joint since this

damage is not normally accessible. Furthermore, the soldering structure is relatively weak in the tangential direction, which in certain cases can create the need for a strengthening structure in the form of a jacket. This is especially the case in those instances in which the flame pressure during the combustion in the rocket motor is very high or in which high lateral forces are present.

A manufacture which uses soldering can further place a limit upon the maximum temperature at which the outlet nozzle can be used.

An alternative method of manufacturing a cooled outlet nozzle is by diffusion-welding of round or rectangular pipes which are arranged in parallel. Even though this method has advantages over the soldering method, it is still relatively expensive.

According to a further manufacturing method, rectangular pipes of constant cross section made from nickel-based steel or stainless steel are used, which pipes are arranged parallel with one another and are welded together. The pipes are spirally wound such that they form an angle with the geometrical axis of the nozzle, which angle increases progressively from the inlet end of the nozzle to its outlet end to form a bell-shaped nozzle wall. The abovementioned joining method has the drawback that those types of rectangular pipes which are commercially available for use with this method are normally made with constant wall thickness. This means that the wall structure of the outlet nozzle cannot be configured for an optimal cooling capacity, since the walls between two mutually adjacent cooling ducts are unnecessarily thick. Moreover, the spiral winding means that the cooling ducts are long and hence give rise to an increased fall in pressure, which for certain running states of the rocket motor is undesirable.

A further method for manufacturing a combustion chamber for rocket motors is described in patent document US 5233755. According to this method, a

corrugated structure is used to form an inner wall, which is joined together with an outer wall by, for example, soldering, diffusion-welding or laser-welding. Cooling ducts are thereby formed, through which a cooling medium can be conducted.

A drawback with the method according to US 5233755 is that, owing to the configuration of the corrugated inner wall, "pockets" are formed at its points of contact against the outer wall. In these portions, a limited flow of the cooling medium is therefore obtained, resulting in locally reduced cooling of the wall structure. This gives rise, in turn, to a risk of overheating of the wall structure. There is additionally a risk of dirt, for example in the form of small particles, accumulating in these pockets. This dirt may subsequently be released from the cooling ducts, which is also a drawback, especially if the cooling medium is also to be used as fuel in the rocket motor.

A further drawback with the manufacturing method according to US 5233755 is that the corrugations in the inner wall lead to a limited part of the cooling medium being allowed to have contact with the inner, warm nozzle wall. This too adversely affects the cooling. Furthermore, the corrugated structure is subjected to bending forces owing to the pressure of the cooling medium inside the structure. Together with the sharp notch at the respective welding joint, these bending forces lead to very high stresses upon the wall structure. This type of structure therefore has limits in terms of its pressure capacity and working life.

The corrugated shape of the distancing material, compared with straight, radially directed distancing elements, leads moreover to increased weight and increased flow resistance.

DESCRIPTION OF THE INVENTION

The object of the present invention is to make available an improved method for manufacturing a cooled outlet nozzle for a rocket motor. This is achieved

by means of a method, the characterizing features of which can be derived from subsequent claim 1.

The invention relates more precisely to a method for manufacturing an outlet nozzle in rocket motors, which outlet nozzle is configured with a wall structure which comprises a plurality of mutually adjacent cooling ducts extending substantially from the inlet end of the outlet nozzle to its outlet end, which method comprises positioning of an outer wall around an inner wall, configuration and positioning of a plurality of distancing elements between the said outer wall and the said inner wall, and joining of the said distancing elements between the said inner wall and the said outer wall, whereupon the said cooling ducts are formed. The invention is characterized in that the joining is realized by means of laser-welding and is designed for the configuration of weld joints which, in a cross section through the wall structure, are substantially T-shaped and have a shape which is rounded towards the inside of the cooling ducts.

As a result of the invention, a host of advantages are obtained. Firstly, a manufacturing method for an outlet nozzle is provided, which can be executed at low cost. Moreover, as a result of the specific geometry in the weld joints, a wall structure is obtained having good nozzle-cooling properties. Moreover, the rounded shape of the weld joints produces an even flow in which there is very little risk of an accumulation of particles.

A further advantage with the invention is that the distancing elements, as a result of their flat configuration in the radial direction in relation to an imaginary axis of symmetry through the outlet nozzle, are not subjected to any bending forces. In addition, a very low concentration of stresses in the weld joints is obtained, owing to the configuration of the radii between the integral components.

The invention further offers low material consumption, low weight, low costs, high reliability and good thermal cooling capacity of the complete wall structure. Moreover, the geometry of the wall structure can be easily adapted to the cooling requirements which pertain to the particular application.

Advantageous embodiments of the invention can be derived from the subsequent contingent claims.

DESCRIPTION OF THE FIGURES

The invention is to be explained in further detail below with reference to a preferred illustrative embodiment and the appended figures, in which:

Figure 1 is a perspective view showing an outlet nozzle according to the present invention,

Figure 2 is a perspective view showing in detail how the outlet nozzle can be manufactured according to a first embodiment of the invention,

Figure 3 is a cross-sectional view showing in detail the wall structure of the outlet nozzle after having been joined together according to the said first embodiment,

Figure 4 is a cross-sectional view showing in detail the wall structure of the outlet nozzle after having been joined together according to a second embodiment of the invention, and

Figure 5 shows how a number of cooling ducts can be arranged in an outlet nozzle manufactured according to the invention.

PREFERRED EMBODIMENTS

Figure 1 shows a diagrammatic and somewhat simplified perspective view of an outlet nozzle 1 which is produced according to the present invention. According to a preferred embodiment, the outlet nozzle 1 is of the type which is used in rocket motors for conducting the combustion gases out of a combustion chamber (not shown) belonging to the rocket motor. The invention is preferably intended for use in rocket motors of the type which are

driven with a liquid fuel, for example liquid hydrog n. The working of such a rocket motor is previously known per se and is therefore not described in detail here.

The outlet nozzle 1 is of the type which is cooled with the aid of a cooling medium, which is preferably also used as motor fuel in the particular rocket motor. The invention is not however limited to outlet nozzles of this type but can also be used in those cases in which the cooling medium is dumped after it has been used for cooling.

The outlet nozzle 1 is manufactured with an outer shape which conforms per se with the prior art, that is to say substantially bell-shaped. Furthermore, the outlet nozzle 1 according to the invention is made up of two walls, more precisely an inner wall 2 and an outer wall 3 which encloses the inner wall 2. The inner wall 2 and the outer wall 3 are separated by special distancing elements 4. These distancing elements 4 are configured according to a first embodiment of the invention such that a number of longitudinal grooves are firstly configured, preferably by milling, in the inner wall 2. The distancing elements 4 are thereby formed as a number of protruding elements 4 extending substantially at right-angles out from the inner wall 2 and to the outer wall 3, that is to say in the radial direction in relation to an imaginary axis of symmetry through the outlet nozzle 1.

According to that which will be described in detail below, the method according to the invention is based upon the distancing elements 4 being joined together by laser-welding. According to the first embodiment, the distancing elements 4 are joined together against the outer wall 3. A number of cooling ducts 5 are thereby formed, extending substantially in parallel in the longitudinal direction of the outlet nozzle 1 from the inlet end 6 of the outlet nozzle 1 to its outlet end 7. In Figure 1 such a cooling duct 5 is illustrat d by dashed lines, which indicate the distancing elements which constitute the limits of the cooling duct 5 in the lateral direction.

The materials which are used for the inner wall 2, the outer wall 3 and the distancing elements 4 are constituted by weldable materials, preferably stainless steel of the type 347 or A286. Alternatively, nickel-based alloys can be used. Examples of such materials are INCO600, INCO625 and Hastaloy x. According to further variants, cobalt-based alloys of the type HAYNES 188 and HAYNES 230 are used in the invention.

Figure 2 is a perspective view of a portion of the wall structure of the outlet nozzle 1, which wall structure is thus substantially constituted by an inner wall 2, an outer wall 3 and a number of distancing elements 4, which are configured as protruding elements by milling of the inner wall 2. According to the invention, the wall structure is joined together by means of laser-welding of the distancing elements 4 against the outer wall 3, whereupon a number of substantially parallel and somewhat recessed grooves 8 appear on the outside of the outer wall 3. Moreover, the abovementioned, substantially parallel cooling ducts 5 are in this case formed, through which a suitable cooling medium is intended to flow during running of the particular rocket motor.

In the laser-welding, a Nd:YAG laser is preferably used, but other types of welding apparatus, for example a CO_2 laser, can also be used according to the invention.

It can be seen from Figure 2 that a weld joint 9 is formed along each section in which the respective distancing element 4 is joined together with the outer wall 3. As the result of precise coordination of the welding method and the dimensions of the components making up the wall structure, a substantially T-shaped and softly rounded shape is obtained in the respective weld joint 9 on the inside of the respective cooling duct 5, which in turn yields a number of advantageous properties of the completed outlet nozzle, for example good cooling properties, high strength and simple manufacture.

A cross section through the wall of the outlet nozzle 1, according to the first embodiment, can be seen in detail in Figure 3. The cross section of the above-described weld joints 9 is illustrated in Figure 3 by dashed lines.

The invention is based upon a laser-welding being carried out such that the outer wall 3 is joined together with the respective distancing element 4. It is assumed that the distancing element 4 has a predetermined thickness t_1, which according to the embodiment is in the order of magnitude of 0.4-1.5 mm. The outer wall 3 further has a predetermined thickness t_2, which is also in the order of magnitude of 0.4-1.5 mm. Through precise coordination of, inter alia, the dimensions of the two walls 2, 3 and the distancing elements 4, according to the invention a weld joint 9 is obtained having the abovementioned T-shape, in which a soft rounding 10 of the inner wall in the respective cooling duct 5 is obtained. Through laser-welding, a radius R of this rounded seam 10 in the order of magnitude of $t_{1min} < R < t_{1max}$ is obtained, which with the above-stated dimensions corresponds to a radius R within the range 0.4-1.5 mm. A depth t_3 of the joint in relation to the top side of the outer wall 3 is further obtained. This depth t_3 is maximally in the order of magnitude of $0.3 \times t_2$, which corresponds to the range 0.12-0.45 mm.

In Figure 4 it is shown how an outlet nozzle can be manufactured by use of a second embodiment of the invention, according to which an inner wall 2' and an outer wall 3 are used. The outer wall 3 is of the same type as in the abovementioned embodiment, but the inner wall 2' is not configured with any milled-out ducts or equivalent. In this second embodiment, a number of separate distancing elements 4' are instead used, which are fixed to the inner wall 2' prior to execution of the laser-welding operation. These distancing elements 4' are thereby used to demarcate a number of cooling ducts 5', through which the particular cooling medium can flow.

According to the second embodiment, the laser-welding is carried out on both the outside and the inside of the wall structure. A number of weld joints 9, 9'

are thereby obtained, extending on both sides of the completed wall structure. As in Figure 3, these weld joints 9, 9' are illustrated in Figure 4 by dashed lines. The weld joints 9, 9' have the same substantially T-shaped cross section as in the abovementioned first embodiment.

The advantage with the second embodiment is that no milling is required of the inner wall 2', thereby affording time and material savings. In this embodiment, the distancing elements 4' must instead be fixed in a suitable manner between the inner wall 2' and the outer wall 3, after which welding is realized on both sides of the wall structure.

In Figure 5, a portion of an outlet nozzle 1 according to the invention is shown, more precisely a portion of the inner wall 2 with associated distancing elements. Where this structure has been manufactured according to the abovementioned first embodiment, these distancing elements are configured by milling. According to that which can be seen in Figure 5, the distancing elements are divided into a first set of distancing elements 4a and a second set of distancing elements 4b, in which the second set is positioned somewhat displaced in the longitudinal direction of the outlet nozzle. This produces a distribution and control of the cooling medium flow in a first cooling duct 5a, which is divided into a second cooling duct 5b and a third cooling duct 5c.

A host of advantages are offered by the invention. Above all it can be stated that the method according to the invention admits very good flexibility in the configuration of an outlet nozzle. For example, the cross-sectional shape of the respective cooling duct 5 can easily be varied by altering parameters such as depth and width in the abovementioned milling of the inner wall 2. The outlet nozzle can thereby easily be dimensioned in a manner which is adjusted according to the thermal load upon the outlet nozzle, which load normally varies along the longitudinal direction of the outlet nozzle. This results, in turn, in an increased working life of such an outlet nozzle.

Furthermore, no increase in weight is obtained in the various weld joints which are formed between the respective distancing elements 4, the inner wall 2' and the outer wall 3. A further advantage is that any defective weld joint is relatively simple to repair. In addition, very favourable flow ratios of the cooling medium are obtained by virtue of the rounded shape of the weld joints 9, 9'.

The invention is not limited to the illustrative embodiments described above and shown in the drawings, but can be varied within the scope of the subsequent claims. For example, the invention can be used irrespective of whether the outlet nozzle is round in shape or is configured as a polygon.

CLAIMS

1. Method for manufacturing an outlet nozzle (1) for use in rocket motors, which outlet nozzle (1) is configured with a wall structure comprising a plurality of mutually adjacent cooling ducts (5; 5') extending substantially from the inlet end (6) of the outlet nozzle (1) to its outlet end (7), which method comprises:

positioning of an outer wall (3) around an inner wall (2),

configuration and positioning of a plurality of distancing elements (4; 4') between the said outer wall (3) and the said inner wall (2), and

joining of the said distancing elements (4; 4') between the said inner wall (2) and the said outer wall (3), whereupon the said cooling ducts (5; 5') are formed,

characterized in that the said joining is realized by means of laser-welding and is designed for the configuration of weld joints (9; 9') which, in a cross section through the wall structure, are substantially T-shaped and have a shape (10) which is rounded towards the inside of the cooling ducts (5; 5').

2. Method according to claim 1, characterized in that the said inner wall (2) is configured with integrated distancing elements (4).

3. Method according to claim 2, characterized in that the said distancing elements (4) are configured by means of milling.

4. Method according to claim 1, characterized in that the said distancing lements (4') are constituted by separate components which are fixed between the said inner wall (2') and the said outer wall (3), after which laser welding is carried out on both sides of the wall structure.

5. Method according to claim 4, characterized in that th said distancing elements (4; 4') have an extent running substantially at right-angles from the inner wall (2; 2') and to the outer wall (3).

6. Method according to any of the preceding claims, characterized in that the said outer wall (3) and the said distancing elements (4; 4') have a thickness in the order of magnitude of 0.4-1.5 mm.

7. Method according to any of the preceding claims, characterized in that the said weld joint (9; 9') has a radius (R) which is in the order of magnitude of 0.4-1.5 mm.

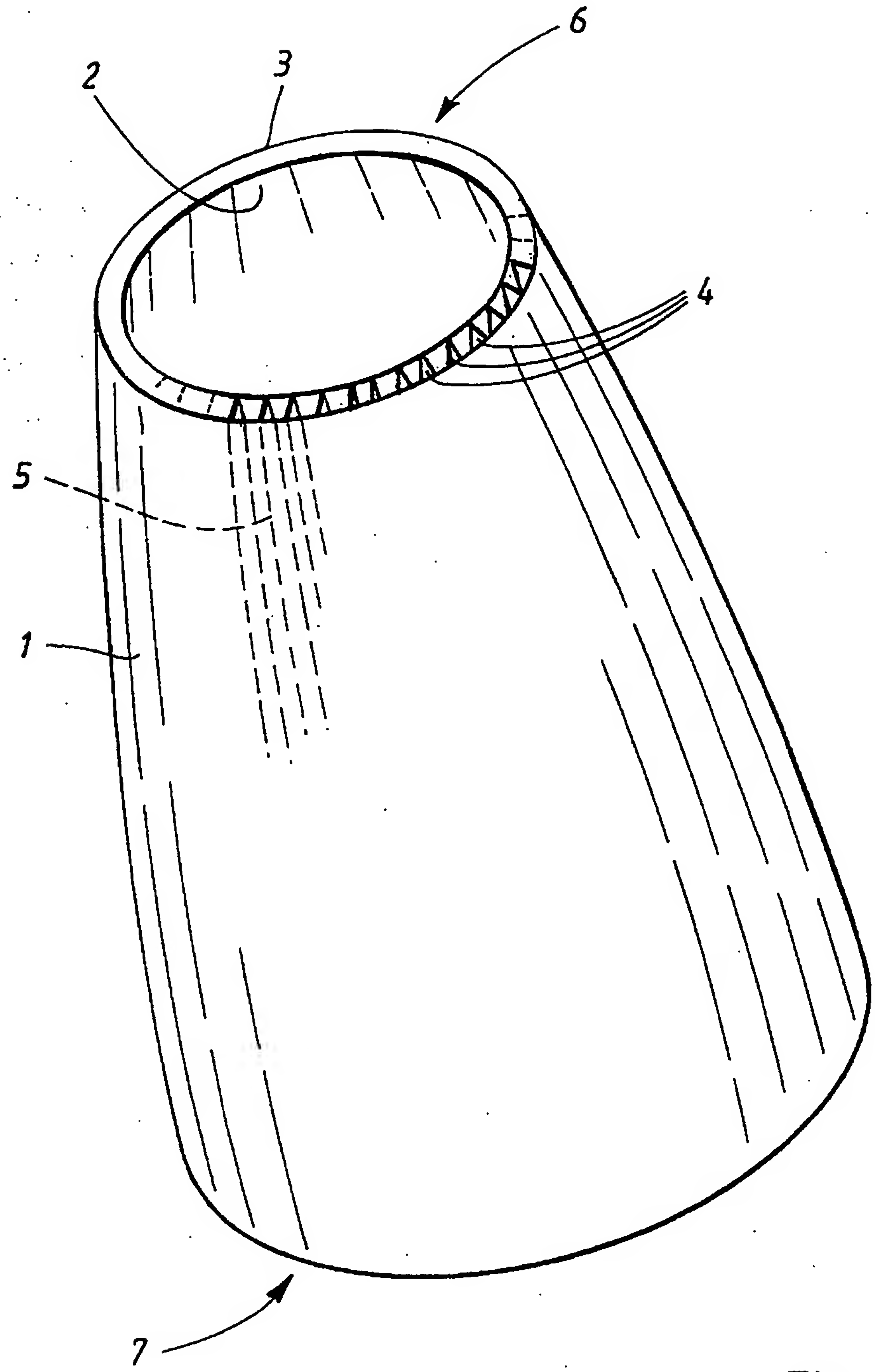

FIG. 1

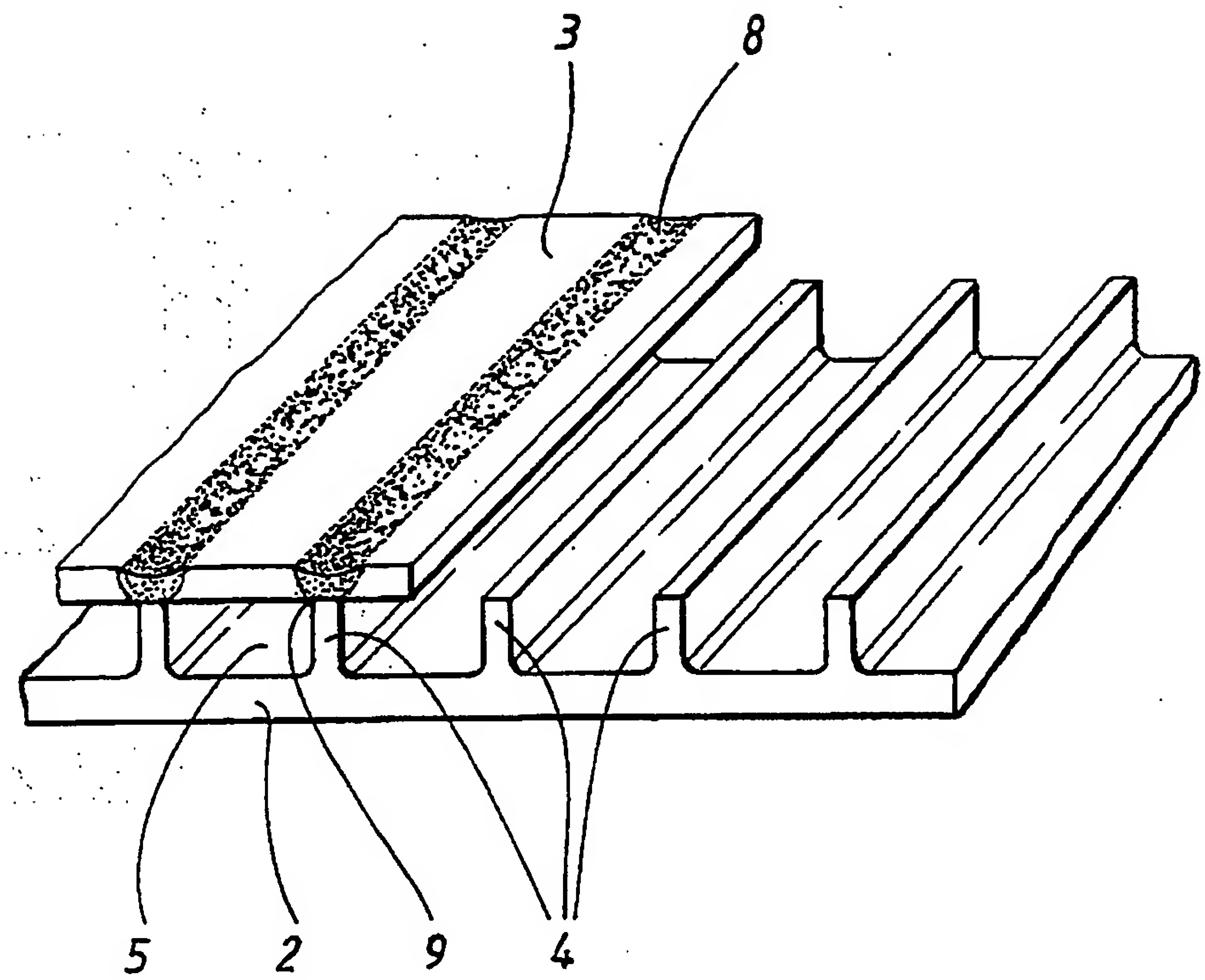

FIG. 2

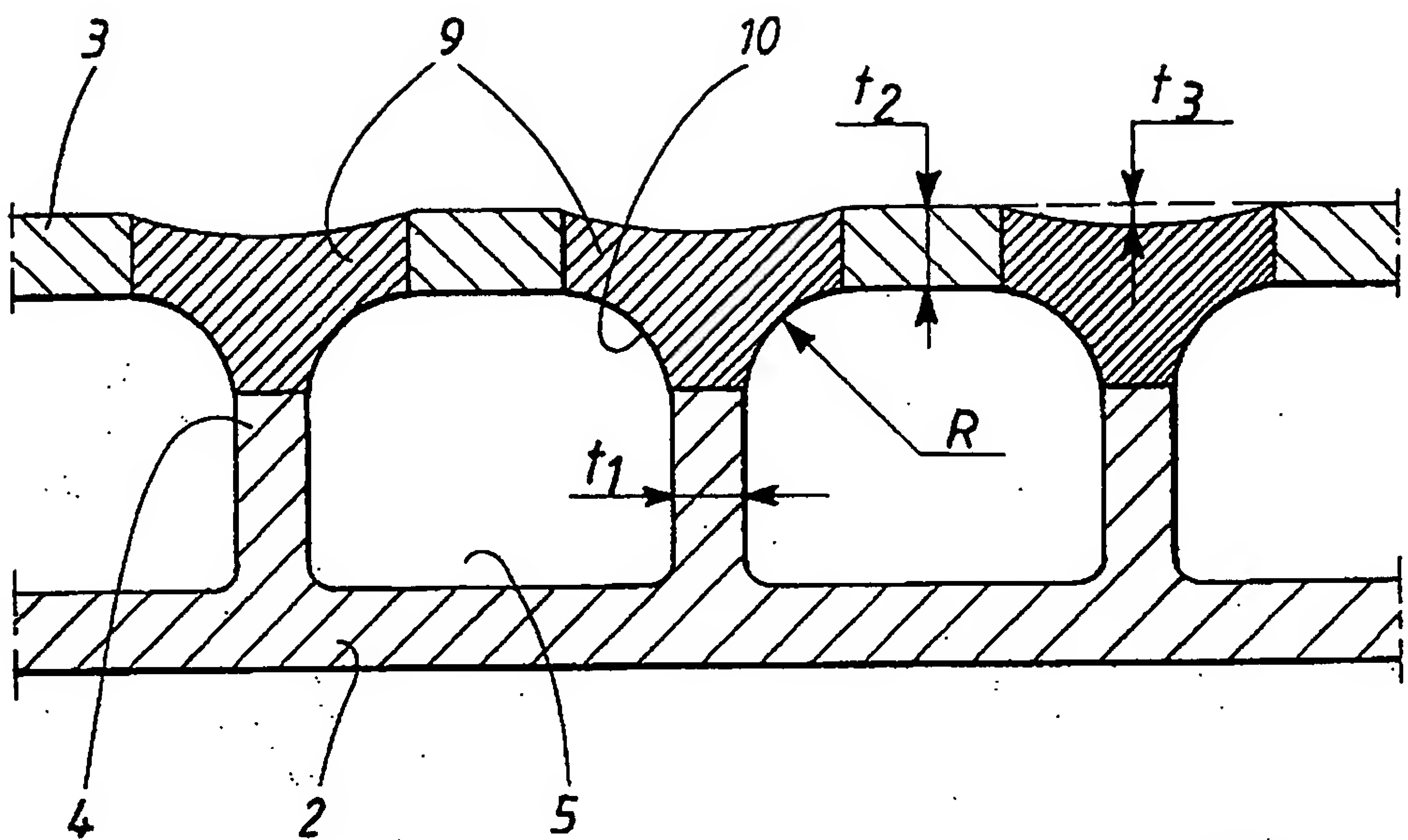

FIG. 3

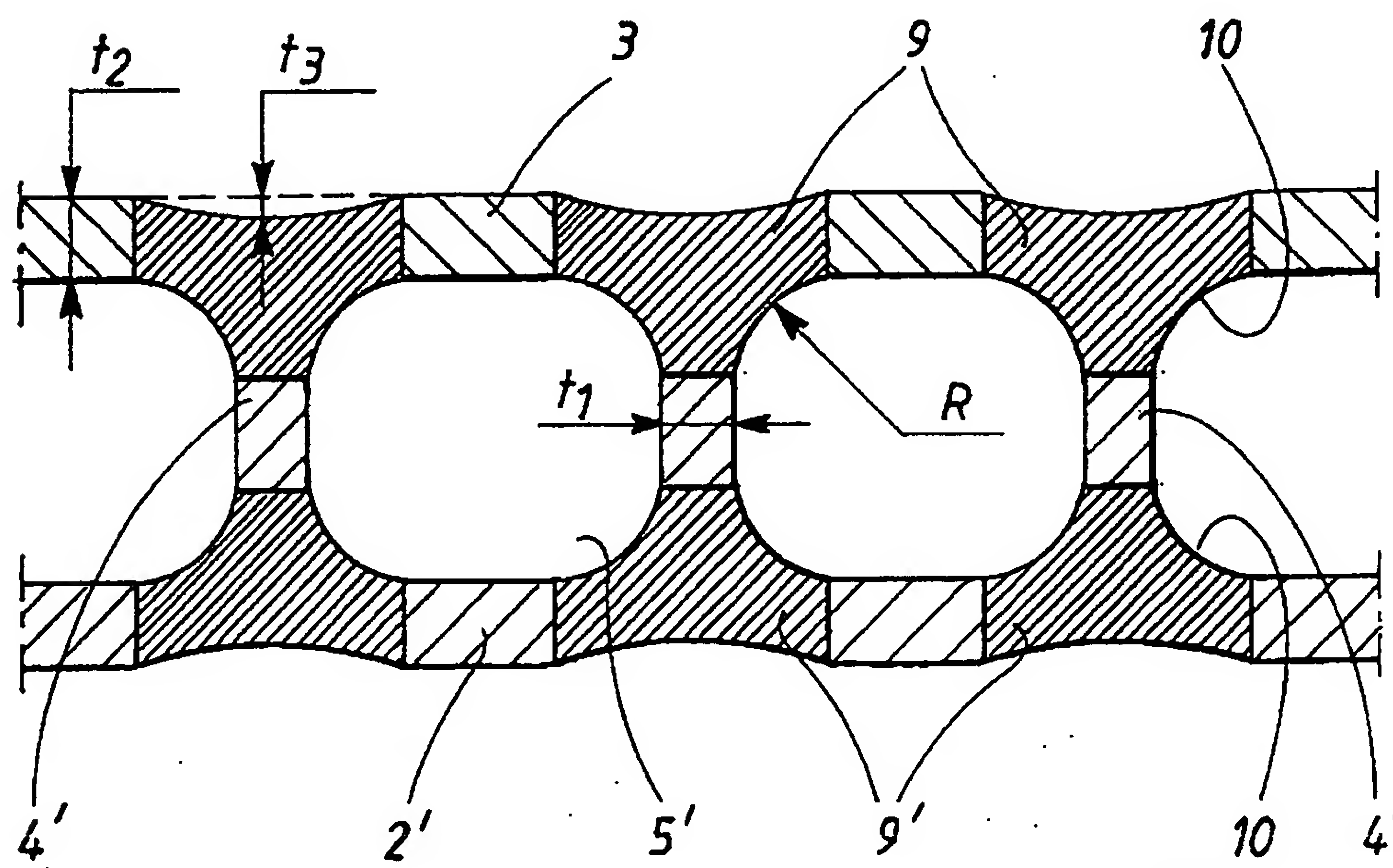

FIG. 4

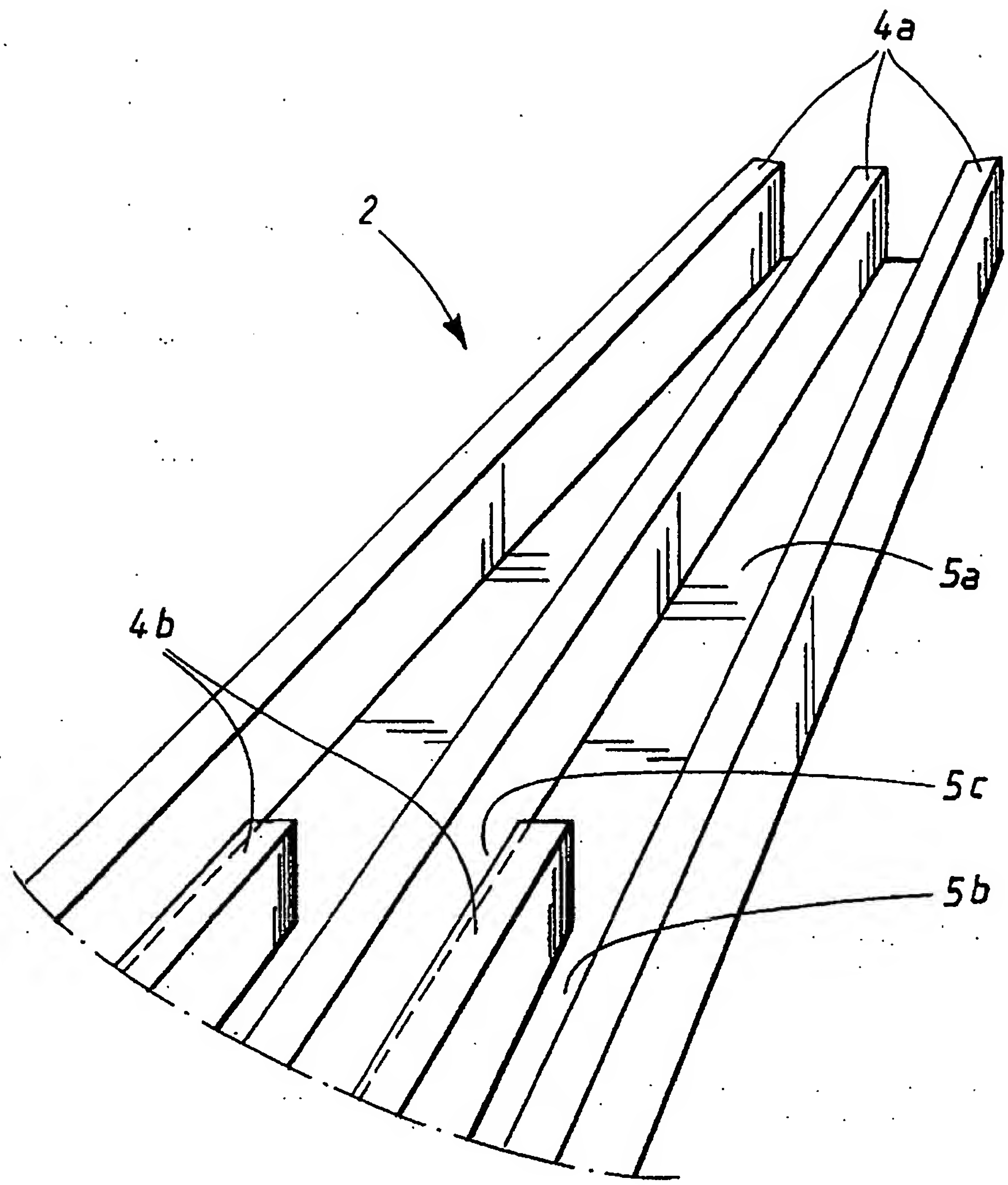

FIG.5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01727

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F02K 9/97, F02K 9/64

According to International Patent Classification (IPC) or to both national classification and IPC

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IPC7: F02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5233755 A (VANDENDRIESSCHE), 10 August 1993 (10.08.93), column 14, line 19 - line 36 --	1-7
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13 January 2000	07 -02- 2000

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INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
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